SO_2 Measurements in a Black Liquor Recovery Boiler With a Tunable Diode Laser

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Background

- SO_2 formed during black liquor combustion is converted to alkali sulfates in the upper (heat exchange) section of the furnace

$$Na_2CO_3 + SO_2 + \tfrac{1}{2} O_2 \rightarrow Na_2SO_4 + CO_2$$

- Understanding of SO_2 reactions in relation to the furnace environment will help identify deposition mechanisms
- Extractive gas analysis techniques are questionable due to post-extraction reactions of SO_2

Recovery Boiler Deposition

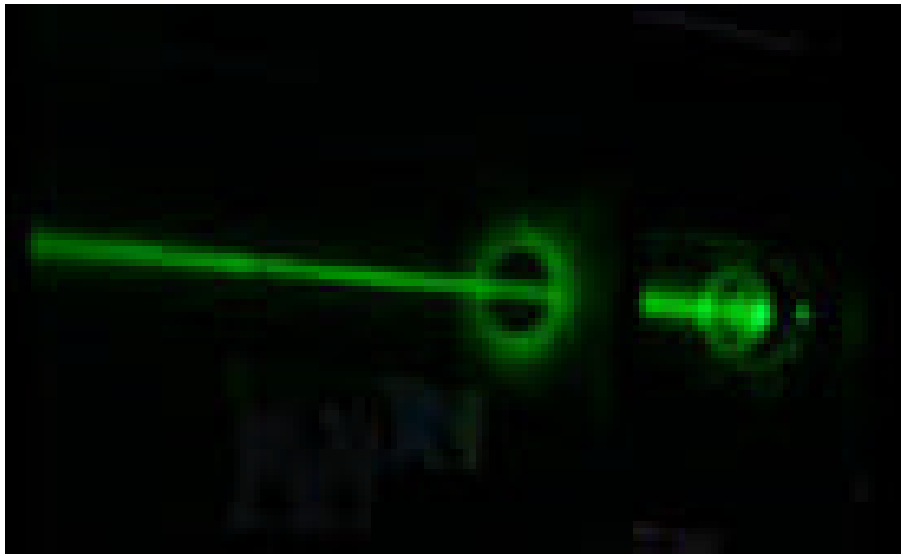
- Deposits are composed primarily of Na_2SO_4
- Deposits may contribute to local tube corrosion
- Fouling of heat exchange surfaces reduces boiler efficiency

Purpose

- Employ a tunable diode laser system to measure SO_2 absorption
- Develop optical system and data analysis routines for on-line SO_2 measurements
- Develop a fieldable probe for *in situ* measurements of SO_2 in recovery boilers

Optical Measurement System Advantages

- Non-extractive
- Possibility of providing real-time measurements
- Minimal equipment exposure to a harsh combustion environment



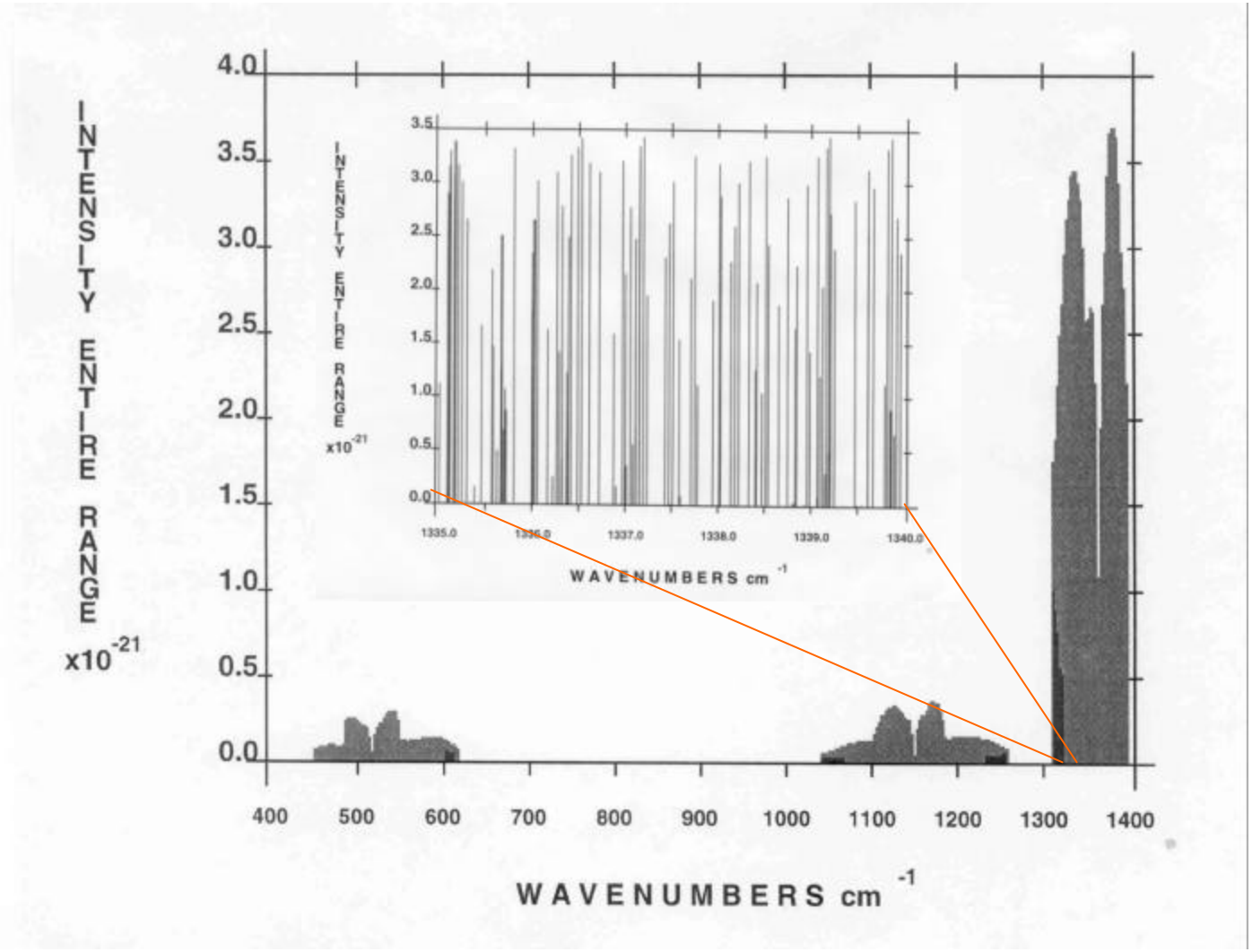
Selection of Mid-IR Absorption Region

- Relatively large absorption line strengths
- Availability of reliable and affordable optical equipment
- Recognizable spectral characteristics

Desirable Spectral Line Characteristics

- Line strength independent of temperature
- Not overlapping with adjacent SO_2 spectral lines
- Not overlapping with spectral lines of other combustion gases

HITRAN Simulation of SO_2 Mid-IR Absorption Spectrum

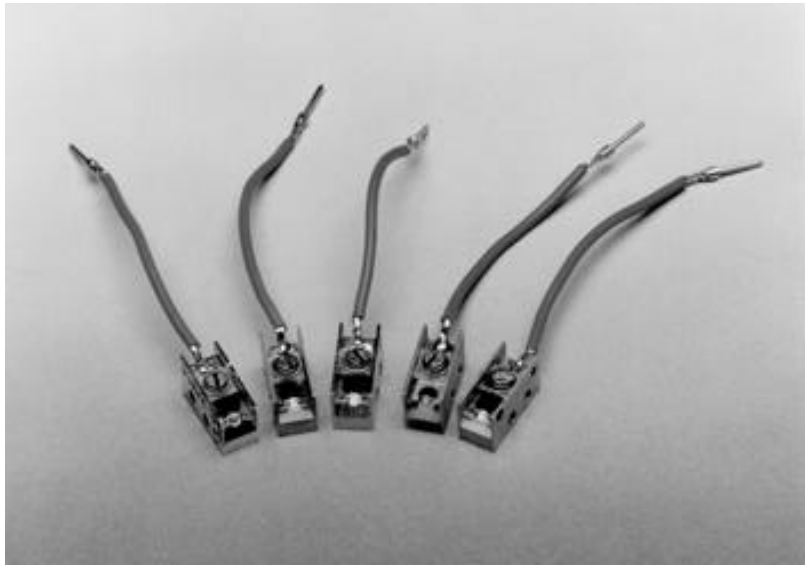


Mid-IR Laser Equipment

- Liquid nitrogen cooled lead salt alloy TDL emit in the region of interest (~1360 cm^{-1}, 7.4 ?m)
- Chalcogenide fiber optics are used for laser signal transmission

Tunable Diode Laser Capabilities

- Very narrow bandwidth able to resolve individual absorption lines
- Rapid modulation allows for signal noise filtering techniques



Correlate SO_2 Concentration to TDL Absorption

- Beer-Lambert Law

$$A = \log\left(\frac{I}{I^0}\right) = \alpha P_{SO_2} L$$

- Determine α experimentally through calibration
- Determine α by derivation from temperature and pressure dependent spectroscopic properties

Sampling Probe

- Necessary to Have Short Path Length in an Optically Dense Environment
- Ideally portable, maneuverable, and removable
- Minimal Physical Influence